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Shear and Tensile failure in fragile rocks: a numerical and an analytical method.

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Fracture failure is usually simulated by means of complex constitutive laws (i.e. plasticity, viscoelasticity, viscoplasticity, creep, etc.) which do not adequately represent the behavior of stiff, fragile rocks when their elastic limit is reached. The interest in the failure mechanism of this type of rocks has increased in the last years due to the progress of geological activities involving injection of fluids at depth (i.e. geological storage of CO_2, enhanced geothermal energy or hydraulic fracturing operations). These applications usually provoke the creation of new fractures and/or the propagation of the pre-existing ones. Moreover, they may induce seismicity even after the shut-in, which is still not completely understood.

In the framework of the EU - FracRisk project, we want to improve the understanding of the failure process in fragile rocks and develop new methods to correctly simulate and predict the failure area in real fracking sites. In this regard, two methods to solve shear and tensile failure have been developed in the hydromechanical-application of the finite element framework Kratos. The first method is based on the analytical solution of Okada (1992), which is included in an iterative process to allow the simulation of the domino effect due to consecutive failure events that may take place. This is a straightforward method which avoids numerical issues but the underlying assumptions impose some restrictions to the modeling of real problems. In order to overcome these drawbacks, a novel numerical method has been developed. This method entails the construction of a Failure Matrix, which consists of the stress state variations in each fracture element due to a perturbation applied to each of them. Therefore, the superposition of the contribution to failure of each fracture element is considered. This Failure Matrix is specific for each model and it is built in a step previous to the beginning of the simulation.

The application of these methods allows us to correctly simulate failure in fragile rocks and to predict failure area and occurrence of seismicity during hydraulic fracturing operations.